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SUPPORTING SENIOR EXECUTIVES' MODELS FOR PLANNING AND CONTROL

Michael E. Treacy

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Massachusetts Institute of Technology
Sloan School of Management

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SUPPORTING SENIOR EXECUTIVES' MODELS FOR PLANNING AND CONTROL

by

Michael E. Treacy

1. Introduction

By now the successful use of models in corporate decision making is well documented and easily observable. McInnes and Carleton [1982], Grinyer and Wooller [1977], Naylor and Schauland [1976], and Traenkle, et al [1975] have all observed the accelerating use of decision support system (DSS) modeling packages. Most of these models are built and used by mid-level analysts to support functional needs in finance, marketing, operations management, and corporate planning. Very few explicit - or formal - models appear to be built or used by senior executives [Rockart and Treacy, 1982]. If these are the people responsible for the formulation of broad strategies and the design of organizational control mechanisms, then it follows that explicit modeling has not had as much impact upon these areas as some proponents would desire.

Yet, these senior executives use models for planning and control. Their models are intuitive and implicit. They are mental representations of reality, abstractions of complex decision contexts, that executives use to simplify the decision process, to identify important variables, and to

generate and evaluate alternatives. They are not usually put down on paper, built into a computer program, analyzed quantitatively, or even viewed as models, but they are models. They are often simple and inelegant and may bear little relationship to "good theory," but they are arguably the most important models for planning and control, because they are powerful and they get used. As one executive put it:

> I bring a lot of knowledge to the party. Just scanning the current status of our operations enables me to see some things that those with less time in the company would not see as important. [Rockart and Treacy, 1982]

This executive clearly has many well-developed implicit models of his operation. These models allow him to quickly assess new information that someone less experienced would have to formally analyze. Figure 1 illustrates this point. Looking at the sales performance reflected in the trend line, one might ask: How well is this company doing? One reaction is that the firm is in trouble because sales are declining. This conclusion is derived from a commonly held implicit model that sales are always rising in a healthy company.

But what if the time frame represented is only twelve months? Then the sales pattern may simply indicate seasonality, and a more complex informal model is required to interpret the data. An experienced executive looking at these numbers may actually see a very healthy situation because his or her model of expected sales was much lower. This example illustrates that data only becomes information when it is interpreted through some implicit model. These models are nothing other than the accumulation of an individual's experience and knowledge.

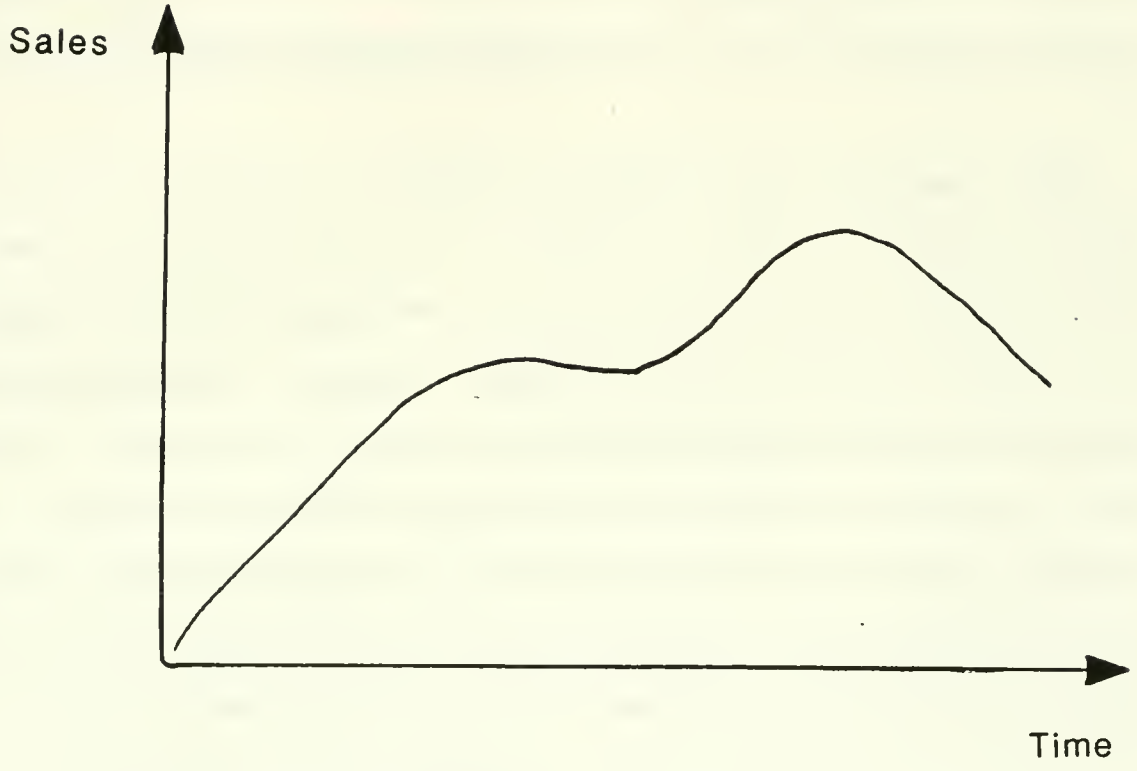


Figure 1

Analyzing Sales Data With Implicit Models

Does the executive really need an explicit or formal model to understand his or her operations? Explicit models are easily shared and they can be analyzed using a range of techniques. Some would argue that even a manager who understood the firm's operations very well could benefit by formal modeling of those operations. Others might argue that what the executive needs is not formal models, but support for his or her implicit modeling, so that the weaknesses of this abstract mental modeling can be reduced.

This paper contributes toward the debate over whether senior executives should be supported with explicit models or by other measures. Our position is a simple one. The answer depends upon the type of decision contexts faced by the executive. We analyze the nature of explicit and implicit models and alternatives for supporting these different modeling processes. To accomplish this, the rest of the paper is divided into several sections. The next section discusses the nature of executive analytic needs and concludes that senior executives' most important problems are complex and unstructured and that complete and formal analyses of these problems are not always possible. The section concludes with a simple categorization of analyses that is later used to discuss alternate types of support systems.

Section 3 develops a set of criteria for evaluating the appropriateness of alternate forms of support for the different analytic needs of senior executives. This is done by examining the potential problems that each form of analysis may incur, for a major objective of support systems is to alleviate or avoid such problems. The final section discusses alternate forms of decision support systems. These different forms derive from differences in

DSS tools, so some time is devoted to a discussion of these tools. One conclusion drawn in this section is that new, emerging forms of modeling, such as fuzzy modeling, may provide support for many of senior executives' most important analytic problems.

2. The Nature of Senior Executive Analysis

There is a lot of use of formal models for planning and control in organizations, but little use of them by senior executives. Several explanations suggest themselves. It may be that senior executives do not possess the necessary skills for model building and analysis or for using a computer. But Rockart and Treacy have found that even among senior executives who use computers for analytic support there is little use made of explicit models [1981, 1982]. It may be that executives don't need formal models; or that their information requirements are simple enough that ad hoc analysis is sufficient. Or, it may be quite the opposite, that the problems they confront are too complex for explicit modeling to be of much benefit. This third possiblility we believe is often closest to the truth.

Much has been written about the roles and information needs of senior executives. Mintzberg [1973] observed that senior managers are often dealing with overwhelming complexity under great time pressure. He found that computer-generated information was of little use to these people. They preferred current and timely information that could be obtained only through informal channels. Gorry and Scott Morton [1971] build upon Anthony's [1965]

framework and characterized the role of senior executives as strategic and largely unstructured. They require support for defining problems, generating alternative solutions, and evaluating them against strategic criteria.

Most of the important planning and control issues that senior executives must face, such as the creation of plans, the control of subordinates, or the analysis of competitive advantage, are highly dependent upon the exact context of the problem. They deal with unique problems for which there are no standard operating procedures. Sufficient and complete knowledge of these problems is very difficult to obtain. Therefore, senior managers must often work under great uncertainty. There is no "normative" approach to planning and control; there is no clear set of decisions which arise in the course of this process. Rather, data concerning both past and current results as well as future plans, are scanned and analyzed, and a set of ad hoc, highly variable decision opportunities occur. As Charles Hitch [1957] observed some years ago:

> The sort of simple explicit model which operations researchers are so proficient in using can certainly reflect most of the significant factors influencing traffic control on the George Washington Bridge, but the proportion of the relevant reality which we can represent by any such model or models in studying, say, a major foreign policy decision, appears to be almost trivial. [p. 718]

Adding to the difficulties of a lack of structure and great uncertainty is what Bellman [1957] calls "the curse of multidimensionality." Managers may aspire to plan and control their firms for the single objective of long term

profitability, but in practice they require many operational objectives, such as present period profit plans and gaining X% of market share, as milestones along the way. These operational objectives are not independent and their relationship to the overall objective of long run profits is often not well understood. Thus, there is further uncertainty introduced by multiple and fuzzy evaluation criteria.

We may conclude that the most important problems of planning and control faced by senior executives are complex and relatively unstructured. These two characteristics, complexity and structure, define a categorization of analytic situations that is helpful in discussing alternate ways of supporting senior executives. In Figure 2 we have illustrated this categorization. For expository purposes, quadrants have been used to define four types of analytic situations. The qualifier "relatively" has been used to indicate that there are not clear demarcations between these categories.

The important problems of planning and control faced by senior managers are analytic situations illustrated in the upper right quadrant: they are complex, relatively unstructured problems.

In the lower left quadrant are analytic situations where the extent of knowledge about the problem is relatively complete and the problem is not very complex. In such situations, problem solving is fairly easy and standard operating procedures can often be routinely applied. In the upper left quadrant are analytic situations that are relatively well structured, but complex. For these problems, standard operating procedures or rules of thumb

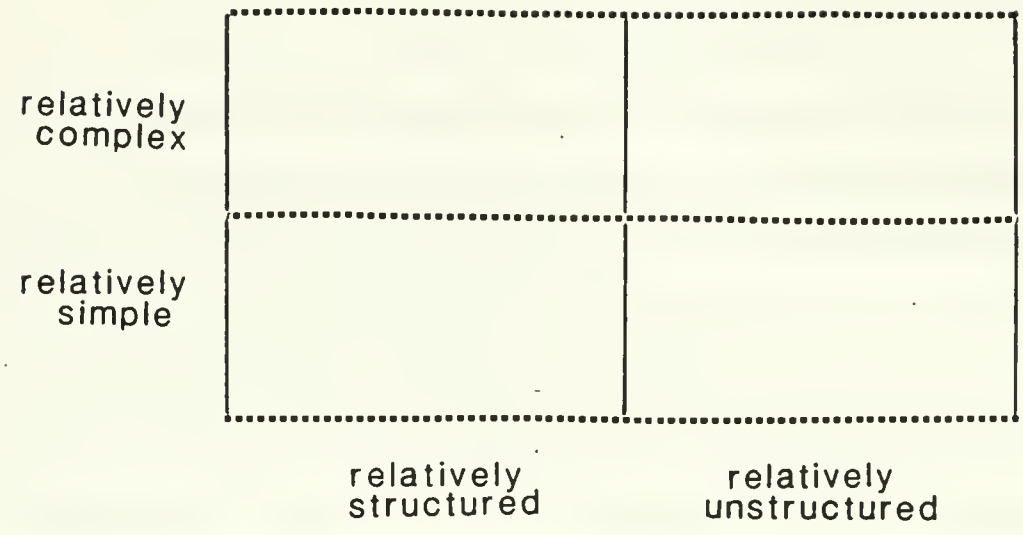


Figure 2

Four Types of Analytic Situations

are often inadequate. Formal analysis, typically in the form of an explicit model, is required to integrate many pieces of information in a structured way.

The difference between these two types of relatively well-structured problems can be illustrated with the problem of inventory reordering. This problem can be viewed as a simple one, to which rules of thumb such as economic order quantity can be applied, or as a complex problem, for which formal models are needed to pull all relevant information together. Material requirements planning is an example of the latter view of the problem. It can be implemented only with the aid of large, formal models. Which view is appropriate for structured problems depends primarily upon the level of effort one wishes to expend to generate a satisfactory solution. For unstructured problems, it also depends upon what is and is not known about the problem.

It is evident from the preceding examples that some problems can be viewed as fitting in any of the four quadrants of Figure 2. An inventory problem can be simple or complex, depending upon how it is viewed, and the greater one's experience and understanding of such problems, the more structure they appear to have. The more unstructured the problem area, the less able are we to provide a complete represention; the more complex the problem area, the more important it is to provide a valid formal analysis. Thus, given a choice, one would opt for the most complete analysis and perhaps a formal analysis, but senior executives, by the nature of the problems they face, are not often given a choice.

For each of the analytic situations illustrated in Figure 2, different analytic approaches can be applied. In particular, one can choose to apply explicit or implicit models to any of these types of problems. Which form of modeling is most appropriate for each type of analytic situation is examined in the next section by developing a list of strengths and weaknesses for each analytic approach. These lists are also used in the subsequent section to determine which form of support system is most appropriate for each type of analytic situation.

3. Potential Problems with Explicit and Implicit Models

Little has developed a list of criteria for good models [1970]. Good models are simple, robust, easy to control, adaptive, easy to communicate with, and as complete as possible. By these criteria, implicit mental models can be good models. They are simple, or at least simple enough that they can be carried around in a person's head. They can be robust. The mental models of experienced executives have been derived from observing complex relationships and events over many years. Subtle relationships, exceptional cases, and critical assumptions can all be part of a good mental model. These implicit models are also easy to control. And one can use them in many ways - to examine alternate scenarios, as part of a larger analytic process, or in conjunction with current information. Mental models are adaptive. If observation negates part of a manager's model, it will probably be modified to account for what was observed. They are as complete as possible, as complete as a manager has been able to comprehend.

Little's criteria for good models, however, can be interpreted another way. They can be viewed as a list of the potential problems introduced when implicit mental models are made explicit. This would account for why mental models so easily meet Little's criteria. Formal models tend to be complicated; they can sometimes give absurd results when certain complexities are missing. They can only be controlled and exercised through whatever facilities are built into the modeling system. They usually are difficult to adapt to other situations and to new information. And explicit models certainly are not easily communicated with by a typical manager unaccustomed to their use.

Not all formal models are this bad. Little provided a list that helps to pick out the good ones. But, in general, formal models suffer more of these ills than do informal models. Or, at least their shortcomings are more obvious. That is why model management is an important and new area of research for those committed to formal models. Konsynski and Dolk [1982], Elam, et al [1980], and Will [1975] each present conceptual schemes for modeling systems that would help automatically to reduce some of the problems with explicit models. If these ideas could be implemented, then we might see more managers approaching problems using formal modeling methods because they would be perceived as more valuable relative to implicit mental models.

Perhaps the most important limitation of mental models is that they do not handle complexity well. It is difficult to mentally integrate complex relationships between variables. Our mental capacities can handle a remarkably broad range of knowledge, but people are not particularly good integrators of that knowledge.

A second problem with these implicit models is that they are hard to manipulate. Once a model adequately describes a phenomenon, one might like to use it to predict or to optimize some aspect of the phenomenon. This requires manipulation of the model, trying alternative scenarios, assessing the impact of uncertainty, and all the other techniques that have become familiar through line-oriented modeling systems. This cannot be done as easily as with a formal mathematical model.

Another problem with mental models is that they are difficult to share with others. And it is even harder to convey the supporting evidence for the model because it is often intangible and gathered through years of experience. This is an important problem because the process of management planning and control is a large and widespread undertaking. It requires specialists in particular areas, such as a strategic planning, accounting, and finance. In addition, it requires the insight, analysis, and guidance which can only be provided by senior line management. Thus, it is a shared activity, involving many different actors with only partly shared perspectives.

A fourth problem with implicit models stems from problems one and two. Mental models are difficult to validate. If they cannot easily be manipulated and if they cannot be easily shared with others, then they are also difficult to test against impartial evidence. We know that people are imperfect information processors. This may result in imperfect, perhaps badly flawed mental models. Without proper validation, these flaws may not surface.

Finally, implicit models are vastly underutilized. Managers often know much more about situations than they bring to the decision-making processes of planning and control. There is a major, uncatalogued resource out there that is not being adequately utilized.

In Figure 3 we have summarized the preceding discussion as a list of the primary potential problems with formal and mental models. A major objective of a support system for executive modeling is to alleviate some of these problems.

Formal Models:	* complicated and hard to understand * difficult to make robust * difficult to control * difficult to adapt * difficult to communicate with
Mental Models	* do not handle complexity well * difficult to manipulate * difficult to share * difficult to validate * uncatalogued and underutilized

Figure 3
Primary Potential Problems with
Formal and Informal Models

4. Alternate Forms of Analytic Support

Among all the buzzwords, jargon, and acronyms of the information systems field, decision support systems (DSS) has proven to be a term of practical and philosophical substance. As a practical matter, DSS focuses on the analysis of data and explicit modeling of the business and its environment. A manager

is viewed not as a passive consumer of information, but as an active participant in the development and use of his or her personalized, supporting computer system. Thus, user control over, not just involvement in, the DSS development process is a fundamental tenet of the approach. Adaptive and evolutionary design are necessary to fit a system to a manager's job. Adaptive design and user control require that the process of support begin with the user's perspective, supporting those parts of the job that the manager wants to maintain, and evolve in the direction that he or she desires. The user is assumed to be knowledgeable about his or her role and, if provided with the appropriate data, software tools, training and guidance, will evolve toward better management. It is the information systems equivalent to Lindblom's [1959] "muddling through." This non-invasive, adaptive philosophy has been key to DSS's extraordinary practical success.

During the past ten years, a host of decision support systems (DSS) generators and software packages have been developed that allow analysts and managers to develop and directly use decision support systems. The differences among the major categories of packages define the alternative forms of analytic support presently available. Figure 4, adapted from Montgomery and Urban [1969], shows the capabilities that have been provided by different DSS generators.

A decision support system provides a manager with another source of information on his or her internal and external business environment. Through an interaction and display facility that may include a command language and query, report writing, and color graphics facilities, the manager can access a

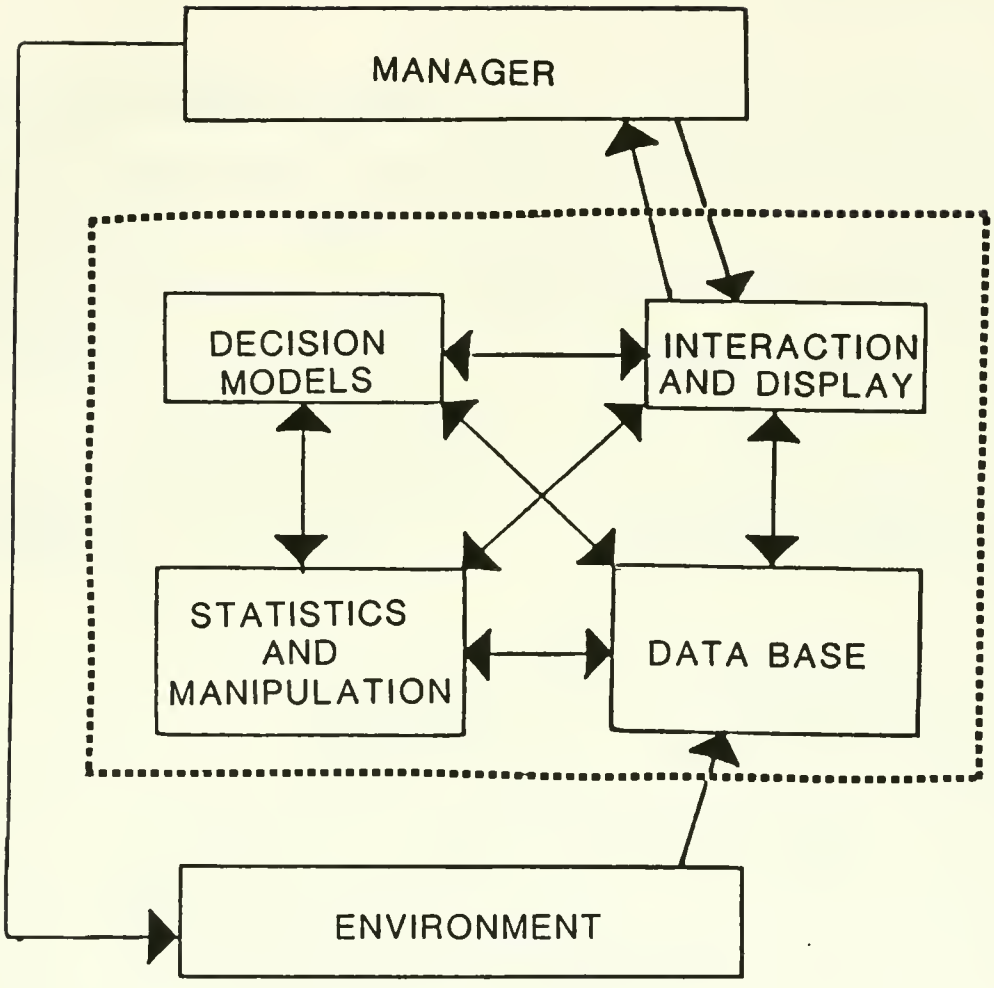


Figure 4

Comprehensive DSS Capabilities

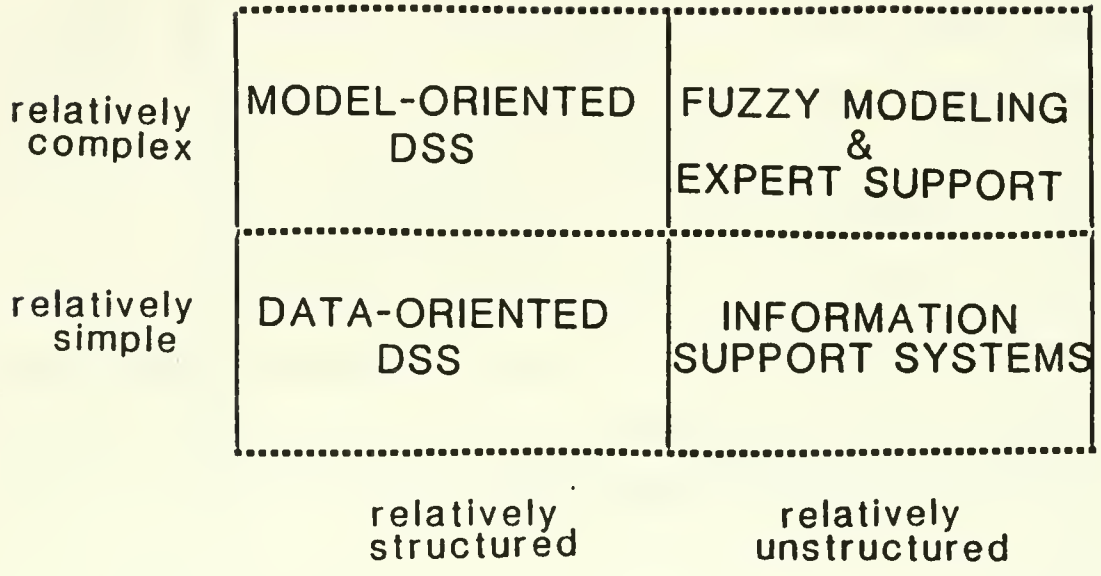
base of data, perform statistical, arithmetic, and other data manipulation functions, and create explicit models of his or her firm, competitors, industry, and the economy.

Figure 4 represents an ideal set of DSS generator capabilities . With these capabilities it is now possible to build many different types of support systems. The question we face is which form of support is best for each of the different analytic situations discussed in Section 2? In Figure 5, four different forms of support are indicated for the four analytic situations. In the rest of this section we will describe each of these forms of support and explain how they relieve the potential problems of explicit and implicit models discussed in the last section.

Model-Oriented DSS for Complex, Well-Structured Problems

Complex problems that are relatively well structured are better analyzed with formal explicit models. In a well-structured problem area, there is enough knowledge to construct a fairly complete representation of the problem context. Hence, formal modeling is possible and for significant problems it is the analytic approach of choice. A system to support the analysis of complex, well-structured problems should be aimed toward providing a formal modeling environment in which modeling is easier and potential problems are reduced.

PROBLEM COMPLEXITY



PROBLEM STRUCTURE

Figure 5

Four Types of Analytic Support

Many of the decision support system generators presently available are focused on just such a form of support. The capabilities of these line-oriented modeling packages are diagrammed in Figure 6.

A line-oriented modeling system, more commonly known as an electronic spreadsheet, gives a manager the ability to define an explicit model of several interrelated variables and calculate the results of the model over several time periods. Typically, the packages allow the user to easily manipulate the model, to test alternate assumptions and scenarios, and to perform sensitivity analyses. These are line-oriented systems in the sense that the model is defined line by line, with each line representing another variable. The packages usually allow a manager to define, solve, and analyze a model and generate reports and graphs. They do not, in general, manage a data base or offer ad hoc analytic capabilities.

These line-oriented modeling systems have won many supporters, but they are still not user-friendly enough to have gained a significant base of senior executive users, except in financial functions. They are, however, ideal for the creation of formal models if the analyst has enough knowledge to be able to create a fairly complete representation of the problem. These packages also address many of the potential problems with formal models. They are designed to make modeling easier, less complicated, and more friendly by providing a powerful but uncomplicated syntax that incorporates both model building and model analysis commands.

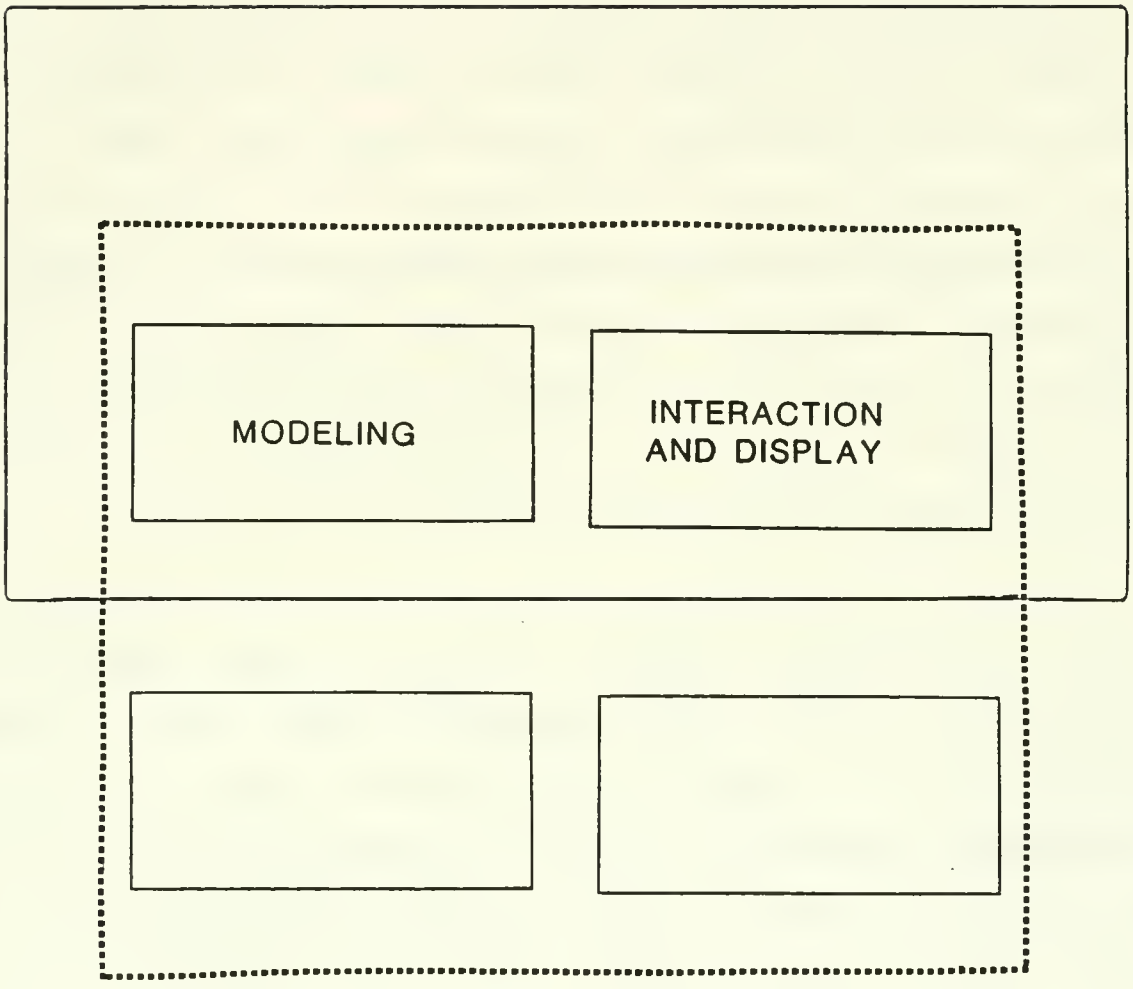


Figure 6

Line-Oriented Modeling Systems

The command languages used in this type of software also make it easier to control models. Changing data values, performing different analyses, and changing the format of printouts are all easier with these packages than with a standard programming language. Because the models are syntactically less complicated and easier to understand, they are also easier to adapt.

The one potential problem that these packages do not help to alleviate is the difficulty in making formal models robust. For example, this software might be used to create a sales forecasting model, but because the package is only a language and has no built-in intelligence about sales forecasting, it can in no way assure that the model is correct.

These line-oriented modeling systems are used extensively for accounting-based models in fairly well-understood areas, such as financial evaluation of projects, budgeting, and consolidation analysis. Most managers understand enough accounting to be able to evolve useful and usable financial models through an interactive process of model building and analysis. Thus, one way that the potential semantic problems of formal models have been overcome is by basing the models upon well-understood accounting principles.

Data-Oriented DSS for Simple, Well-Structured Problems

Simple and well-structured problems are fairly easy to support. In monitoring and tracking sales, for example, what managers need is access to data that they can use to trigger rules of thumb or standard operating

procedures. This is the type of support offered by data-oriented DSS. These systems are built to provide managers with ready access to a pre-defined base of data. They are often used as supplements for paper-based reporting systems because they offer more flexible reporting formats as well as a limited set of analytic tools. These systems are used to support monitoring in areas where an executive has a fairly well-formed mental model of expected performance. But because the data covers only a limited area and analytic tools are also limited, data-oriented DSS are only appropriate for recurring, reasonably-structured problem areas such as monitoring performance vs. budget.

The software that data-oriented decision support systems are based upon is quite different from the software used for model-oriented systems. It is usually called "friendly" (that is, easy to learn and use) data base management systems (DBMS). The capabilities of this class of software are illustrated in Figure 7. Some well-known products in the marketplace are FOCUS, RAMIS, NOMAD, and DBASEII. These packages provide a manager with a facility for managing and accessing a large base of data, creating reports and graphs, and performing very limited analysis upon the data. They give managers the ability to choose the data that they wish to see and to format it in reports or graphs as they wish to see it. Unfortunately, as with much of the line-oriented modeling software, the user interfaces for these data base packages are not yet friendly enough to encourage widespread use by executives.

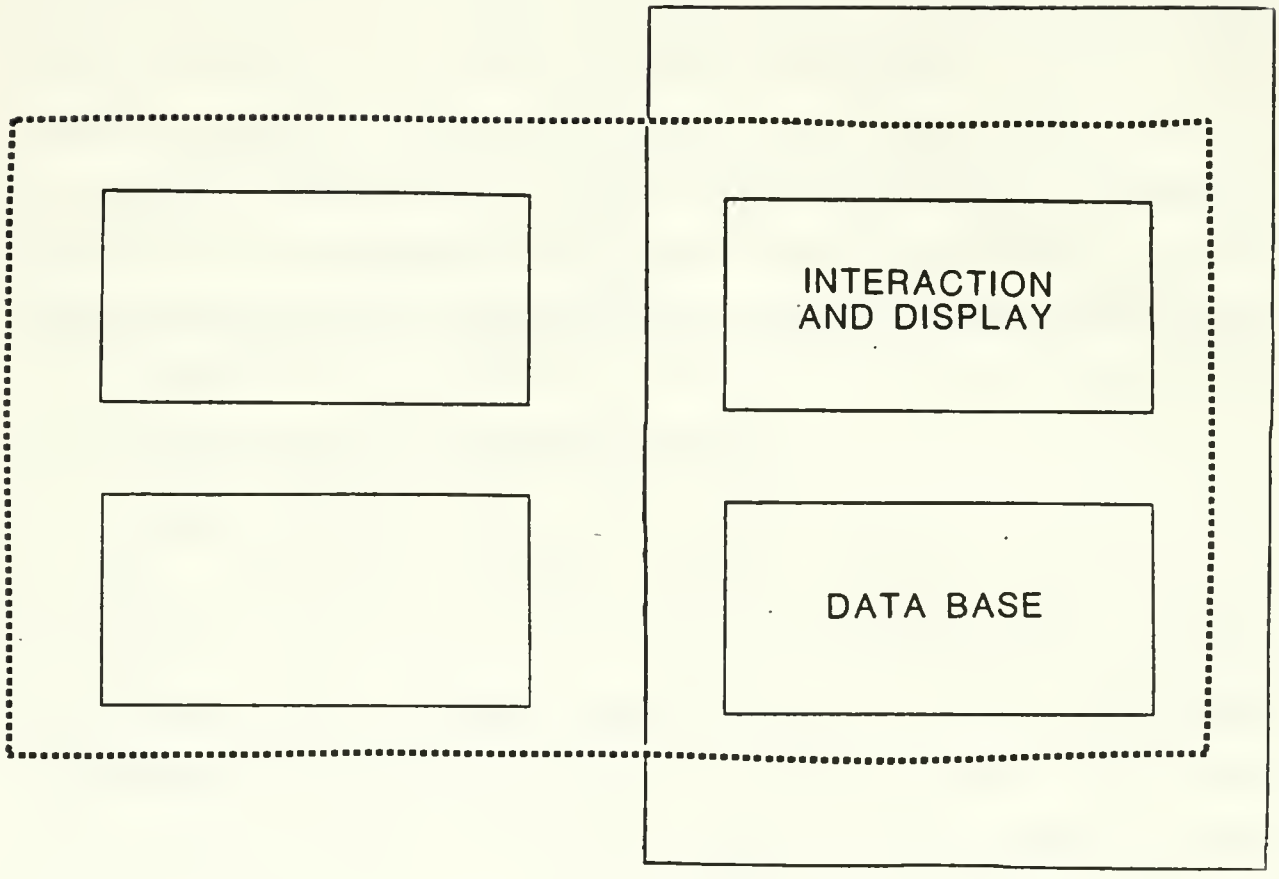


Figure 7

Friendly Data Base Management Systems

Information Support for Simple, Unstructured Problems

Even for relatively simple problems, the more unstructured they are, the more difficult it becomes to pre-define the data and reports that are appropriate for support. Concurrently, the implicit mental models that are used to address problems such as succession planning or how a firm is doing relative to its competition become subject to questionable validity, manipulability, and sharability. Support for simple but unstructured problems must be based upon at least three design elements: (1) a large base of data, (2) a set of ad hoc analytic tools, and (3) sharing of the system by managers with common information needs. These design elements define an information support system, which is the most widely implemented form of support for senior executives.

In an increasing number of companies, a level of data and software commonality have been established; their information support systems resembles Figure 8. Bases of data have been established for groups of individuals who naturally draw upon the same type of data. In one company, the strategic planners and controllers created one base of data, while the marketing managers and market researchers created another. At Northwest Industries in Chicago, corporate staff and executives all draw from one base of data. [Rockart and Treacy, 1982] In both firms, it was the managers and analysts who established what data would be in the data bases and what data definitions would be used. And, despite the common data bases, in every case the users also maintain their own personal data files.

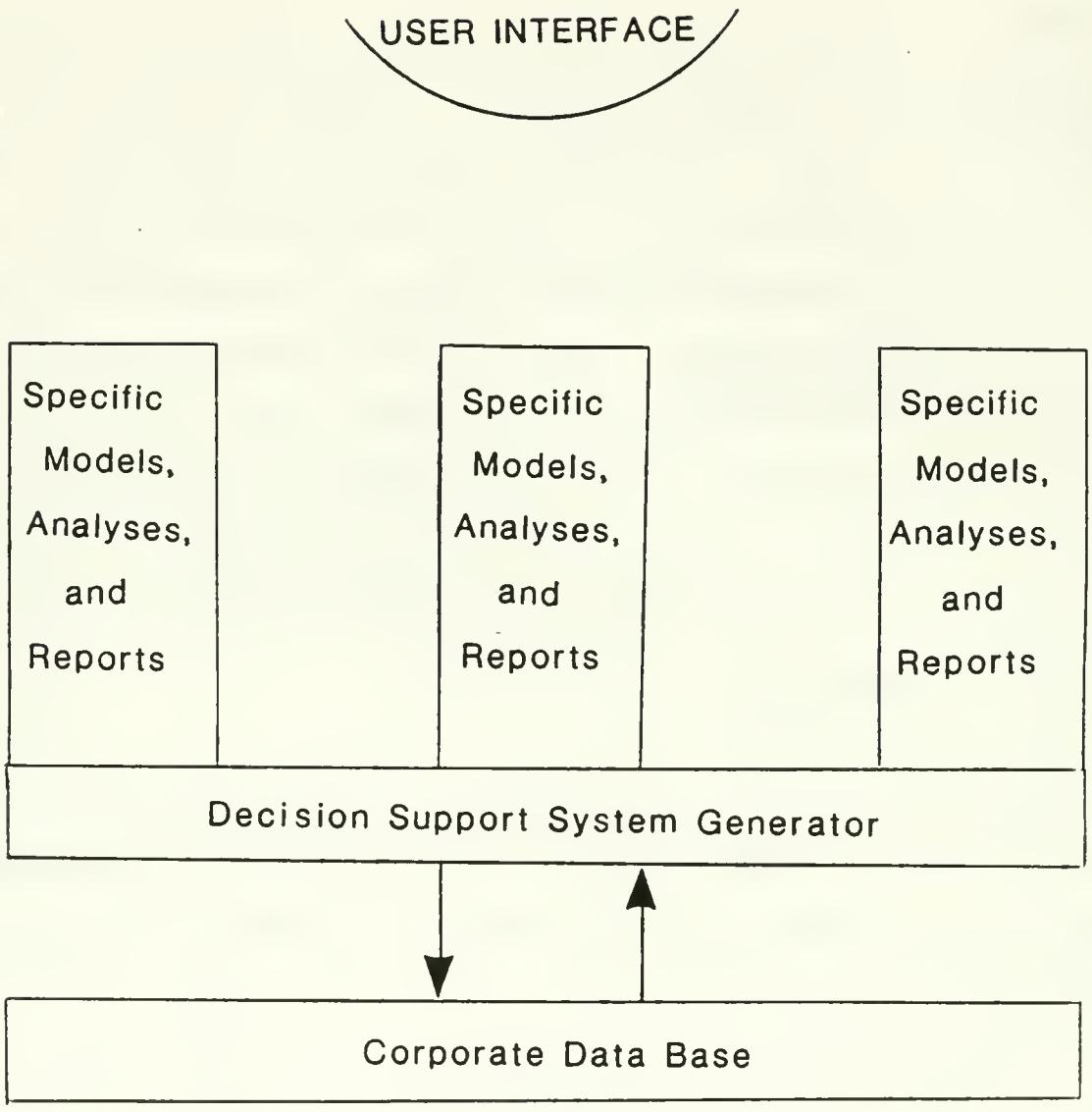


Figure 8

Information Support Systems

These data bases evolve. With present information requirements analysis techniques and with the existing state of data management in most firms, only about half the needed data can be put into a data base on the first pass. In addition, the nature of the executive's job is one of constant change and new data are often needed to support new problems and opportunities.

Each of these three design elements helps to reduce problems of validity and sharing mental models. A large base of data combined with analytic tools allows the manager to build, explore and test his or her implicit models against the data. In this way, data analysis serves to help validate mental models. One of the potential problems with these implicit models is that they are difficult to share, difficult to transfer to another person. A shared information support system provides a language and a medium for communicating implicit models. If managers support their implicit models through a system, then the models become more transferable with the sharing of data and analysis.

The software that underlies information support systems must have both data management and ad hoc analysis capabilities. The packages must be comprehensive and contain all the elements shown in Figure 4.

Fuzzy Modeling and Expert Support for Complex and Unstructured Problems

Most implicit mental models are fuzzy, but computer-based modeling systems are precise. Until we can develop fuzzy modeling systems, most of the useful, computer-based support for implicit models will be provided through data

retrieval, analysis, and the transforming of data into different formats. Fuzzy modeling systems will allow a manager to externalize crude, incomplete, and inconsistent internal models without having to translate them into complete and internally-consistent models like those found in model-oriented DSS.

Fuzzy models are used by senior managers all the time. For example, in a pricing decision, a manager might bring into play the following rules:

(1) Our price should be about two times direct costs.
(2) Our price should be just below our dominant competitor's price.
(3) If our competitor's prices go too high, we should price for increased market share.

None of these statements is in a form precise enough to be used in a standard formal modeling system. Each statement begs for refinement. With a fuzzy modeling system, however, the above statements form a model of a pricing decision that could be solved. The results of that solution clearly would not be satisfactory, but it is a useful starting point that prompts the manager for a more refined representation of his or her mental model.

Fuzzy models are ideally suited to complex and relatively unstructured problems, the type of problems that senior executives must commonly deal with. These models have the power of formal modeling systems to handle complexity. But, conceptually, fuzzy models compensate for many of the potential flaws of formal models such as the requirements for completeness, precision and consistency.

Fuzzy modeling systems can create and analyze models that are incompletely specified, internally inconsistent, or ambiguous in their causality. The systems compensate for these flaws in the models by intelligently choosing assumptions that will allow the model to be analyzed. Along with the results, these assumptions are automatically added to the model and shown to the manager who can modify them for further analysis.

The development of fuzzy modeling systems might sound as if is many years away. It is not. The technology for fuzzy modeling has been developed in the artificial intelligence community and is becoming widely available. One product already has an approximate reasoning capability that provides some fuzzy modeling features.

Another important development from the artificial intelligence community, relevant to the support of relatively complex and unstructured decision situations, is human expert systems. To date, such systems have been oriented toward replicating expert capabilities on a computer. A recent development has been to reorient the applications toward providing computer-based expert assistants that can support rather than replace a decision maker. For example, one company has developed "smart" statistical tools. When a computer is given sales data, for instance, the system will analyze the characteristics of the data, taking into account such things as seasonality, and will then choose the most appropriate sales forecasting tool.

The conceptual underpinnings of expert support systems have been developed under the rubric of "model management systems." According to Elam, et al

[1980], a model management system,

> can be viewed as a system that dynamically constructs a decision aid in response to a particular problem. This is accomplished by drawing on a knowledge base of models that captures the technical expertise of a management scientist plus an understanding of the basic activities involved in a given decision-making environment...

These fuzzy modeling and expert support tools are not yet available. It is little wonder, therefore, that we have had difficulty supporting the modeling needs of senior executives faced with complex and unstructured problems. Of the three other forms of support, information support systems are the most popular for executive support systems because they offer meaningful support for a manager's implicit mental models. But, information support fails as a support mechanism for complex problems. That is why many senior managers might feel that executive support cannot help them with their "real" problems, their complex problems. For them, we must wait a little longer for the emergence of some "real" executive support tools.

While we are waiting, it benefits us not to think too narrowly about models or modeling systems. In reading some of the literature on models used for planning and control, one might assume that all important models are explicit, mathematical representations of problems in a spreadsheet format. This paper has explored another type of model - implicit models - and how to best support managers' uses of them. As support technology evolves, it will challenge us to rethink our concept of a model and its role in managerial decision making.

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